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VISUAL LOCALIZATION IN THE HORIZONTAL PLANE

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Casual observation indicates that one can, with a fair degree of accuracy, determine when a visual object is in the same horizontal plane with the eyes, or as commonly put, when an object is on a level with the eyes. That this ability is dependent in some measure upon environmental cues seems evident. The question arises, does an individual when prevented from using these external aids give evidence of this same ability to any considerable degree; that is, are there any internal cues, for example kinaesthetic cues such as furnished by the ocular muscles, which function in such a situation? In this paper I am reporting a preliminary investigation of the matter. Answers relating to two questions were sought: (1) What ability does an individual have for ascertaining that an object is in the same horizontal plane as the eyes when the usual external aids are lacking? (2) Does practice improve an individual's ability in this function?

THE APPARATUS

The nature of the problem necessitated the use of a dark room, with a small point of light as the visual object. An adaptation of the psycho-physical method of "average error" was used. Two pieces of apparatus were needed: first, a device for displaying a small point of light at varying heights; second, a suitable device for keeping the subject's head in the normal position with his eyes at a fixed level.

To meet the first need I devised a "homolometer," as I have called it for convenience. This consists essentially of an upright standard, 234 cm. in height, constructed of two pieces of lumber so arranged as to form a guide or track in which a small carriage slides. By means of a simple windlass arrangement this carriage

can be raised or lowered through a perpendicular distance of 120 cm. It supports a small metal box which contains a 15 watt lamp; a dim point of light is emitted by virtue of a circular hole, 2 mm. in diameter; the light intensity is reduced by means of several thicknesses of frosted glass. A short strip of metal, serving as an indicator, is fastened rigidly to one side of this light carriage at a point exactly even with the light; it extends horizontally and passes directly in front of a long strip of record paper, which is fastened in a convenient manner to the upright standard. By means of this indicator the experimenter, even in the darkness, can determine and record the setting of the light which the subject has judged to be level with his eyes. With the true level marked on this record strip it is an easy matter for the experimenter to measure accurately the magnitude of the errors of judgment.

To meet the second need a substantial platform was constructed; height 34 cm., width 79 cm., and length 96 cm. Toward the front of this platform at a convenient height for a seated subject, a rigid bar or shelf was fixed, bearing a screen with an aperture, 8.5 cm. x 3.5 cm. The bar serves as a head rest and by use of it the subject's head may be so adjusted as to bring the eyes to a constant locus just behind the aperture. Simple measurements were made to ascertain the normal head posture of each subject as he stood in his usual erect position, the chin and the tip of the nose being used as reference points. By means of such measures I was able to reproduce the normal head posture of each subject when the head was properly adjusted in the head rest.

These two pieces of apparatus were set up in a dark-room. In this experiment the observation platform was so placed that the subject's eyes were exactly three meters from the homolometer, and 148 cm. above floor level. The point on the homolometer scale which was exactly level with the subject's eyes was ascertained by means of an accurate spirit level. Once ascertained, of course it did not change; though I took the precaution to check it several times during the course of the experiment.

SUBJECTS

Seventeen subjects were used, all of whom were students in Denison University, with the single exception of one faculty member; ten were men and seven were women. Certain of them wore glasses, but this seemed to make no difference in the results. In table 1, an asterisk indicates those who wore glasses.

PROCEDURE

With the head measures taken and the subject seated in proper position on the observation platform, the needed instructions were read to him. The room light was turned off and in order that the subject's eyes might become dark adapted, he sat in darkness for several minutes before proceding. Then the homolometer light was turned on, thus presenting a small point of light to the subject, either above or below the level of his eyes. At his instructions the experimenter raised or lowered it until the subject declared it level with his eyes. A slow and uniform movement of the light was maintained at all times. Immediately after each judgment the light was darkened while the experimenter recorded the setting on the record strip and moved the light carriage to a new setting. Again the light was presented and the experimenter raised or lowered it at the instructions of the subject until he believed it level with his eyes. Six series of twelve judgments each, or 72 judgments in all were made at each sitting. A brief rest period of approximately two minutes (with room illuminated) was had between the third and fourth series, while the experimenter was changing the record strip. The usual precautions for avoiding "space errors" were observed; that is, the light was presented an equal number of times from each of the three different positions above the true level and below the true level, after an order determined by chance. At no time did the subject see the homolometer since it was shielded by a curtain whenever the room was illuminated. Nor did the subject know at any time anything about the nature of the errors he was making. Every known precaution was taken to guard against assistance from external sources.

PRESENTATION AND DISCUSSION OF DATA

I. What ability does an individual have for ascertaining that an object is in the same horizontal plane as the eyes, when the usual external cues are lacking?

As an adequate measure of a subject's ability in judging when the point of light stood at a level with his eyes I have calculated the

TABLE 1

Showing the most probable locus of the estimated level for each subject

SUBJECTS	NUMBER OF JUDGMENTS	AVERAGE ESTIMATED LEVEL	S.D.	PER CENT JUDGMENTS ABOVE TRUE LEVEL
Mr. A...............................	216	−6.27°	2.04	00.0
Miss B..............................	216	−4.65	2.50	2.7
Miss C..............................	432	−4.89	3.20	6.7
Mr. D..............................	432	−4.77	3.56	9.5
Mr. E...............................	432	−4.83	3.27	6.2
Miss F..............................	432	+2.98	3.74	78.0
Miss G.............................	432	−7.40	2.14	0.0
Mr. H*..............................	144	−7.46	2.04	0.0
Mr. I................................	72	−2.84	1.71	6.9
Mr. J*...............................	72	−7.91	.96	0.0
Mr. K...............................	72	−6.47	2.30	0.0
Miss L..............................	72	−2.45	1.88	11.1
Mr. M*..............................	72	−4.65	2.96	0.0
Mr. N...............................	72	+3.73	1.67	97.2
Mr. O*..............................	72	−0.41	1.67	41.6
Mr. P...............................	72	−4.48	1.40	0.0
Miss Q..............................	72	−5.66	2.10	2.8
Average for all subjects......................		−4.42°	2.30	15.4

most probable locus of his judgments. That is, the mean of the errors was found, taking into account the algebraic signs, an error above the true level being designated as positive and an error below as negative. The most probable locus I have termed the "average estimated level." An examination of the data summarized in table 1 reveals the following facts.

(1) Individuals differ in marked degree with respect to their ability to judge when the point of light is level with the eyes. This is indicated by the wide range of the average estimated levels; it extends from 3.73 degrees above the true level for Mr. N. to 7.91 degrees below the true level for Mr. J., making a total range of 11.64 degrees. The true level is approximated by a single individual, Mr. O., whose average estimated level is −0.41 (±0.13) degrees; 58 per cent of his judgments fell below the true level. The sixteen remaining subjects definitely miss the true level.

(2) The tendency to make the constant error of dropping the estimated levels below the true level is obvious. The average estimated level for all subjects is 4.42 (S. D., 2.30) degrees below the true level, a difference sufficiently great to warrant the statement that it can not be due to chance. Only two of the seventeen subjects, Miss F. and Mr. N., show an average estimated level above the true level; the average estimated level of the other fifteen subjects fell consistently below the true level. In fact, seven of this number never went above the true level in a single judgment; six others went above the true level in only 5.8 per cent of their judgments. Of all judgments made, but 15.4 per cent were above the true level.

(3) The amount of error seems to be a function of the direction of movement of the point of light. This is clearly shown by the scores of the eight individuals who served at two or more sittings; these data are presented in table 2.

(a) The average estimated level is uniformly lower when a downward movement of the point of light is involved than when an upward movement is required. I have calculated the average estimated level for all judgments when the starting position of the light was above the true level and hence necessitated lowering to bring it to the true level; such judgments are termed "downward." Likewise I have calculated the average estimated level for all judgments requiring a raising of the light, terming them "upward." It is seen that in each case the downward judgments are lower on the homolometer scale. This means that all subjects, excepting Miss F., missed the true level more on downward

judgments than on upward judgments. For subject C. who exhibited the least difference in this respect, a difference of 1.19 degrees is found; while for subject E. the difference amounts to 3.60 degrees. The average estimated level for all downward judgments is 5.82 degrees below the true level, and for all upward judgments it is 3.47 degrees below, making an actual difference then of 2.35 degrees.

(b) The average estimated level is nearer the true level when the direction of movement of the light is opposite to the direction of the subject's constant error. An examination of the data

TABLE 2

Showing the most probable locus of the estimated level in judgments when downward movement of the point of light was involved, and when upward movement was involved

SUBJECT	DOWNWARD JUDGMENTS			UPWARD JUDGMENTS		
	Number	Estimated level	S.D.	Number	Estimated level	S.D.
A	108	−7.04°	1.94	108	−5.30°	1.46
B	108	−5.74	2.64	108	−3.57	1.47
C	216	−5.49	3.51	216	−4.30	2.73
D	216	−6.22	3.32	216	−3.36	3.19
E	216	−6.69	2.53	216	−3.09	2.94
F	216	+1.19	3.24	216	+4.82	3.28
G	216	−7.94	2.61	216	−6.62	1.73
H	72	−8.61	1.51	72	−6.32	1.84
Average..	171	−5.82°	2.66	171	−3.47°	2.33

reveals the fact that all subjects whose average estimated levels fell below the true level show an estimated level that is more nearly correct on the upward judgments. In the case of Miss F., whose average estimated level falls above the true level, the estimated level on downward judgments was best.

(4) There is a tendency for subjects to drop their average estimated level lower and lower at any given sitting, the farther in time they are removed from a view of their surroundings. It will be recalled that the work of a given sitting was divided into six series of twelve judgments each, with a brief rest between the

third and fourth series, at which time the room was illuminated. In table 3, I have recorded the average estimated levels for the combined first and fourth, second and fifth, third and sixth series respectively, thus getting the average estimated level as judged at three different stages of time with respect to the subject's view of room surroundings.   Examination of these data

TABLE 3

Showing the average estimated level at three different stages during sitting of the first day

SUBJECT	SERIES 1 AND 4	SERIES 2 AND 5	SERIES 3 AND 6
A	−4.8°	−6.2°	−6.8°
B	−4.2	−5.2	−5.0
C	−6.9	−7.7	−7.8
D	+0.7	−0.6	−1.4
E	−4.1	−5.3	−6.6
F	+2.4	+1.9	+0.1
G	−4.1	−4.9	−6.5
H	−6.8	−6.7	−6.6
I	−2.5	−3.2	−3.0
J	−8.0	−8.7	−8.5
K	−6.9	−6.3	−5.1
L	−2.1	−2.7	−3.0
M	−4.1	−4.4	−5.4
N	+4.5	+3.3	+3.4
O	−0.8	−0.7	−0.1
P	−3.8	−4.6	−5.0
Q	−4.4	−5.9	−6.8
Average........	−3.3°	−4.0°	−4.4°

shows that the majority of the subjects do conform to this tendency of dropping their estimates lower and lower the farther in time they are removed from a view of their surroundings.   The averages for all subjects give average estimated levels of 3.3, 4.0, 4.4 degrees respectively for the three successive stages.

II.   Does practice improve an individual's ability for ascertaining that an object is in the same horizontal plane as the eyes, when the usual external cues are lacking?

Within the limits of this present experiment, the evidence shows that practice is not beneficial.   Two of the subjects practiced for three days upon this function and five others practiced for six days.   The average gross error of judgment for each day was calculated, that is, taking no account of the direction of the error; any improvement in ability should of course result in decreased errors.   An examination of these data, summarized in table 4, reveals that improvement is consistently true for only a single subject, Miss C.   Mr. D., on the other hand, shows the reverse tendency, growing constantly worse on successive days.   If a composite practice curve should be plotted, using

TABLE 4

Showing the average gross errors for each day (algebraic signs not considered) for those subjects having three or more sittings

SUBJECT	1ST DAY	2ND DAY	3RD DAY	4TH DAY	5TH DAY	6TH DAY
C	7.50°	7.16°	6.92°	4.42°	2.33°	2.30°
D	1.45°	3.58°	5.07°	5.57°	6.40°	8.30°
E	5.32°	8.21°	4.32°	4.22°	4.13°	4.18°
F	2.98°	3.33°	3.77°	5.53°	3.48°	5.60°
G	4.97°	7.45°	7.50°	7.78°	7.90°	8.13°
A	5.95°	6.85°	6.33°			
B	4.55°	4.03°	5.43°			
Average..	4.67°	5.81°	5.62°	5.50°	4.85°	5.70°

the daily mean of the average gross errors of judgment, i.e., 4.67, 5.81, 5.62, 5.50, 4.85 and 5.70 degrees, the resulting curve will in no wise resemble the expected learning curve.   It is possible that beneficial results might have come with an extension of practice, though the experimenter has no reason for believing that this would be the case.

SUMMARY

The results of this investigation may be summarized as follows:
I. Concerning the ability that individuals have in this function.
a. Individuals differ in marked degree, the average estimated

levels ranging from 3.73 degrees above the true level to 7.91 degrees below.

b. There is an obvious tendency for most individuals to drop the average estimated level below the true level, the average for the estimated level of all subjects being 4.42 degrees below.

c. The amount of error seems to be a function of the direction of movement of the point of light.

d. There is a tendency for subjects to drop the estimated level lower and lower as judgments progress during any given sitting.

II. Concerning improvement in this function with practice.

Within the limits of this present investigation the evidence would warrant the conclusion that practice does not bring improvement.

PETROLEUM PRODUCTS FOR INTERNAL COMBUSTION ENGINES[1]

MILTON FINLEY

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THE INTERNAL COMBUSTION ENGINE

An internal combustion petroleum engine is a self contained unit arranged to receive within its cylinder, vaporizer, or combustion space, by varying methods in different types, either liquid heavy crude and fuel oil, petroleum, distillates or other similar fuels. Such fuels are first vaporized and intimately mingled in the combustion space with air compressed by the inward move-

[1] Thesis submitted in competition for the Woodland Prize. This prize is offered annually under the terms of the will of J. Ernest Woodland, and is open to juniors in Denison University. The thesis is printed without editorial correction.—THE EDITOR.

ment of the piston of the engine. Ignition of the explosive mixture thus formed then takes place with consequent evolution of the heat energy contained in the fuel which is thus converted into work.

The first internal combustion engine was constructed by Huyghens in 1680. It was very different from any engine now made. Instead of using gas, oil or petrol, it used gunpowder as the fuel. The gunpowder was made to explode, thus driving out the air and causing a vacuum. This tended to pull the piston down, and the motion of the piston could then be used to do any work so given to it. However, this engine was not a practical success, nor were any others using gunpowder as a fuel. The first gas engine was constructed by Rev. W. Cecil in 1820, who exploded a mixture of hydrogen and air in a cylinder; the principle was the same as that used in the old gunpowder engines and was likewise unsuccessful. It was, however, a step forward in the development of our modern internal combustion engine. The first practically successful gas engine was built by Lenoir in 1860. It was what is technically known as a "Non-compression" engine, whereas the present day engine is a compression engine. Lenoir's engine used about seven times as much fuel as the modern engine. In 1866 Otto and Langen produced an engine which had a loose piston in the cylinder. The piston was driven upwards by an explosion, and then, when the gases were expanded it began to fall by gravity. As soon as it began to fall, it caught on a ratchet, and work was accomplished by the force of gravity. This engine also was not very successful, and its action was spasmodic. In 1876, Otto produced the first four-cycle gas engine. The principle of this engine had been clearly defined by Beau De Roches fourteen years before, but he had never built a successful engine. Otto was a more practical man, however, and succeeded in making the first successful model. In this type of engine there is compression and consequent expansion by explosion, as contrasted with the Lenoir "Non-compression" engine. In 1880 Dugald Clerk constructed an engine partaking of both the Lenoir and Otto principles, in that it was a two-cycle engine, but the mixture of air and gas was brought about in a separate cylinder, instead of the working

cylinder.   This engine has come to be a very widely used type. Daimler, in 1895, brought out the first well known high speed petrol engine for automobiles.   It uses the Otto four-cycle principle, but uses petrol vapor instead of gas.   The most radical change in the gas engine came in 1897, when Diesel constructed the first Diesel engine.   We need only to mention the latest change in the gas engine, that of Humphrey in 1909.   In this engine, a column of water is used instead of the cast iron piston. The gas is exploded in the cylinder and drives the water from a low level tank to a high level one.   This type of engine is used where turbines are to be driven, and deserves only passing mention here.

There are two mechanically and thermo-dynamically distinct types of internal combustion engine.   Both, of course, work on the principle of compression and ignition of the fuel, but the manner in which this is accomplished and the various types of fuel best adapted to each type vary widely.   There are two divisions of the types of engines.   These may be called the two-cycle- and four-cycle-operating engines.   In the four-cycle engine, two revolutions of the crank shaft or four strokes of the piston are necessary for the complete cycle.   The first stroke of the piston downward is called the suction stroke.   Here the fuel is vaporized and sucked into the cylinder.   The second stroke, upward, is a compression stroke, in which the fuel vapor is highly heated by compression.   The third cycle is a downward thrust of the piston caused by the ignition and consequent expansion of the vaporized fuel.   The fourth cycle of stroke is the upward stroke in which the exhaust gases, formed by combustion, are expelled.

The idea back of the two-cycle engine is the same as the four-cycle, except that the four processes are combined in two strokes of the piston.   If, for instance, the compression stroke has just been completed, we have the expansion stroke, and at the end of this downward stroke the exhaust valves are opened.   A blast of pure air then enters and blows out the exhaust gases.   Next the piston moves upward and compresses this air, causing a high temperature.   At the point of greatest compression a jet of fuel is injected into the cylinder and becomes ignited by the high temperature.

Thus it expands and causes the power stroke, and the whole process is repeated.

There are advantages to both the two- and four-cycle engine. The four-cycle engine gives (A) a lower fuel consumption, (B) more complete combustion of fuel, (C) simplicity of construction, as the crank case and moving parts are open and easily accessible, (D) use of lowest grades of fuel oil without the tendency towards carbonization on pistons or piston rings and exhaust passages. With the two-cycle engine there are also the advantages of (A) absence of exhaust- and air inlet-valves and valve-motion necessary with the four-cycle type, (B) power of piston displacement developed per unit of volume as compared with the four-cycle type is seventy five to ninety per cent greater, (C) more even crank effort, (D) lighter fly-wheel than with four-cycle type.

With the four-cycle engine there are several disadvantages which may be mentioned here, although they have no direct bearing on the choice and use of combustion fuels. These are (A) variable crank-pin effort which necessitates a heavy fly-wheel, (B) a greater total weight of engine per H.P. developed, (C) necessity of exhaust- and air-valves and valve-motion. With the two-cycle type we have (A) inferior combustion of fuel and smoky and dangerous exhaust gases, (B) greater lubrication required and more cooling water necessary, (C) increased fuel consumption, (D) possible leakage of air when compressed in crank case.

In the first type of engine, the fuel is sprayed against a highly heated surface, which gasifies it, and it is ignited by an electric spark. Included in this type of engine we have the so-called "hot-surface" oil engine, the gasoline or petrol engine, of which the automobile and other lighter engines are examples.

The second type of engine is called the Diesel engine. Here we have the fuel atomized with air, injected into the cylinder, and ignited. There is no sudden explosion, causing a shock, but a constant pressure exerted by the expanding gas. The first commercial Diesel engine was built by Rudolph Diesel in Augsburg, Germany, in 1897. It has a great many advantages over the other type of engine. Because of the possibility of using fuels not usable in other types of engines, it is the most economical engine

built.   The Diesel is adapted to the use of petroleums, lignite-tar oils, and vegetable oils.   Because of the fact that the Diesel engine runs at a temperature of from 400° to 500°C., and that petroleums gasify around this temperature, it is found that petroleums make the best fuel for the Diesel engine.   Those petroleum products richest in saturated hydrocarbons burn most readily in this type, while a decreasing hydrogen-content means increasing resistance to combustion.   A list of the desirable elements of a petroleum fuel for the Diesel engine is as follows:

(a) Complete combustion, without any residue of soot, coke, or ash.
(b) Freedom from mechanical impurities that may clog pipes or vents.
(c) Fluid condition at ordinary working temperature so that it can flow to pumps and valves.
(d) Freedom from highly volatile oils which may ignite easily and cause dangerous fires.
(e) High heating value.
(f) Freedom from water, as this lowers the heating value and may prevent ignition.

PETROLEUM FUELS

Petroleum is found in a great many parts of the world, but there are only fourteen or fifteen places where it is produced in quantities large enough to be marketed.   The United States is by far the chief producer of petroleum and petroleum products, and it stands far out in the front of all the combined production of the world.   It also leads in the amount of petroleum products consumed.   The chief oil fields of the United States are (1) the Appalachian oil field, which embraces the territory of New York, Pennsylvania, West Virginia, and Tennessee.   Petroleums found in this territory are the so-called paraffin bases, having a comparatively high specific gravity, and are characterized by freedom from sulphur and asphalt content.   This is the highest grade of crude petroleum, and has never been equalled by any other crude oil.   Seven per cent of the total gasoline production comes from paraffin base crude petroleum.   (2) The Lima-Indiana oil field, which takes in western Ohio and Indiana.   These crude oils are

characterized by a high sulphur content, and a freedom from asphalt. Owing to the expense necessary to remove sulphur during the refining process, this petroleum has been rather backward in development, but with the invention of processes whereby this difficulty has been overcome, this field is rapidly developing. (3) The Mid-continent fields which include Oklahoma and Kansas. This region is the foremost oil producer in the United States. The petroleum occurring here is a paraffin-base, low specific gravity oil, having some asphalt present. (5) The Central and North Texas oil fields are similar to those of the Mid-continent. (6) The Louisiana oil fields are also a part of the great Mid-continent and Texas oil fields. (7) The Gulf Coast oil field produces a heavy, asphalt-base crude oil, similar to the Lima-Indiana field in that there is some sulphur present. They are, however, much more easily treated than the Lima-Indiana crudes, and are, therefore, more widely developed. (8) The Wyoming fields yield a petroleum resembling the Lima-Indiana fields both as to high sulphur content and paraffin-base. (9) The California oil fields yield a heavy, asphaltic base crude oil. There is, however, a wide variation in oils from California, although all contain a high percentage of asphalt. California ranks first in production of petroleum by states and second in districts of the United States. (10) Other sources of petroleum are to be found in Michigan, Arkansas, Alabama, New Mexico, Montana, and Alaska. These areas are developing gradually with the slowing up of the other more important sources.

The following table will give a list of the most important sources of petroleum in the world and the percentage produced by each, up to and including the year 1924.

	Production per cent
United States	70.5
Mexico	13.8
Russia	4.5
Persia	3.2
Dutch East India	2.0
Roumania	1.3
Venezuela	0.9
India	0.8

Peru... 0.8
Poland.. 0.5
Argentina... 0.4
British Borneo (Sarawak).. 0.4
Trinidad.. 0.4
Japan (Formosa)... 0.2
Other sources... 0.3

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Petroleums are classified, generally into three groups.   These are:

      (1) Paraffin Base crude oils
      (2) Asphalt Base crude oils
      (3) Mixed Base crude oils

Generally speaking, the petroleums are mixtures of chemical compounds of carbon and hydrogen, called hydrocarbons, with varying small amounts of nitrogen, oxygen, and sulphur. The nitrogen, oxygen, and sulphur are all found combined with the hydrocarbons as derivatives, along with some small amounts of the free element.

Oxygen, as found in petroleum, exists in a free state, but as a rule is combined with the fatty acids and their derivatives, naphthenic acids, phenols, asphalts, and certain resinous bodies. The total oxygen content is around two to three per cent. Sulphur is found in crude oil as free sulphur, hydrogen sulphide gas, and organic sulphur compounds such as thiophenes, having the general formula $CnHnS$, thiopanes with the formula CnH_2nS, and sulphones with the general formula CnH_2nSO_2. Small amounts of alkyl sulfides, mercaptans, and alkyl sulfates are also present. Nitrogen is found in all petroleums, in varying small amounts as quinoline, with a formula in C_9H_7N and pyridine having a formula C_5H_5N. These compounds are derivatives of the aromatic hydrocarbons, of which benzene (C_6H_6) is the mother liquor.

A list of the most common paraffin hydrocarbons found in petroleum is given in the following table. These hydrocarbons are present in varying proportions, so it is not possible to give

the percentage composition, yet they themselves do not vary to any great extent.   Along with the paraffin hydrocarbons are also small quantities of the aromatic hydrocarbons, mainly of benzol and several of its homologues.   These are, however, not present in any great amount.

PARAFFIN HYDROCARBONS

Liquids

Pentane	Undecane
Hexane	Duodecane
Heptane	Tridecane
Octane	Tetradecane
Nonane	Pentadecane
Decane	Hexadecane

Solids

Octodecane	Octocosane
Eicosane	Nonocosane
Tricosane	Hentriacontane
Tetracosane	Dotriacontane
Pentacosane	Tetratriacontane
Hexacosane	Pentatriacontane

Naphthenes

Cyclopentane	Methylcyclohexane
Methylcyclopentane	Cycloheptane
Dimethylcyclopentane	Methylcycloheptane
Cyclohexane	Cyclo-octane

Saturated aliphatics

Normal Pentane	Normal Heptane
Isopentane	Iso-heptane
Normal Hexane	Normal Octane
Iso-hexane	Iso-octane

Olefines

Normal Amylene	Heptylene
Hexylene	Octylene

We need not go deeply into the process of refining of petroleum. Essentially it consists in heating a petroleum to such a temperature that the heavy molecules decompose into lighter molecules with the consequent production of mixtures of lower boiling point. The process of refining itself illustrates the well known tendency of organic compounds to decompose upon heating.   Also petroleums having the heaviest molecules decompose most readily. Ordinarily the process of refining a crude petroleum occupies from one to three days, depending on the source and type of the

petroleum as well as the equipment used. However, temperature and pressure are the governing factors of the refining process. The higher temperature and pressure used the more completely is the petroleum decomposed. (Fig. 1.)

There is, however, one objection to the cracking of petroleum in making petroleum fuels, especially gasoline. This is that a so-called "cracked gasoline" leaves a carbon or soot residue upon burning. Hall, in making experiments upon cracked and distillate gasoline, finds that carburetion is perhaps a larger factor in soot deposition than is the method of obtaining the gasoline. He found that a cracked gasoline burned more slowly, hence imparting power during the whole stroke of the piston. There was, however, a greater deposition of soot. The distillate gasoline exploded instantaneously and gave off its power in the fraction of a stroke, and did not leave so much residue. Research on this problem is being carried out, with the idea that perhaps a blend of distillate and cracked gasoline may give better results. At the present time the Pittsburgh laboratory of the Bureau of Mines is working on the problem.

There are three general types of petroleum cracking processes. These may be called:

(1) Cracking at atmospheric pressure.
(2) Cracking under pressure in stills.
(3) Cracking under pressure in small vessels and tubes.

The second named process is by far the most widely used, because of the high degree of cracking or decomposition that is possible. In the first process, there are too many unsaturated or olefin hydrocarbons formed, which causes irregularity both in product and production. Cracking under pressure eliminates this condition to some extent.

The advantage of cracking at high pressure in stills lies in that the reactions occurring at the decomposition of the crude petroleum take place in the gaseous state. In this condition the hydrocarbon is fully expanded, hence there is no danger connected with the process. Also, under high pressure, a higher temperature is possible which makes for a more complete decom-

Refining Chart of Pennsylvania Petroleum
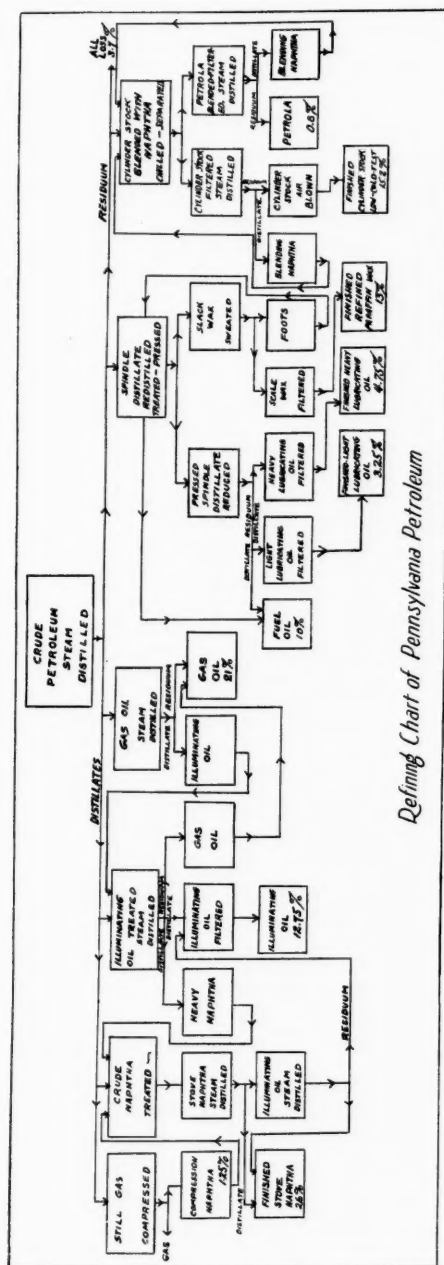
Fig. 1

position of the petroleum. This, of course, gives a greater yield of products. The speed of reaction is also greatly increased, and may be controlled at will. A reason given for the increased yield of compounds having a lower boiling point is that hydrogen is formed at high temperature and pressure, which unites to form more hydrocarbons than would otherwise be formed.

Before refining a crude petroleum, it must be tested so that a general idea of the constituents may be determined. An outline of these tests is as follows:

(*a*) Specific gravity and Beaume gravity.
(*b*) Color, fluorescence, and odor.
(*c*) Viscosity.
(*d*) Content of water and bottom settlings.
(*e*) Heat of combustion.
(*f*) Sulphur content.
(*g*) Percentage of nitrogen and oxygen.
(*h*) Determination of carbon and hydrogen.
(*i*) Index of refraction.
(*j*) Coefficient of expansion, specific heat and heat of vaporization.
(*k*) Estimation of paraffin wax.
(*l*) Estimation of asphalt content.

In commercial practice this determination of a petroleum involves the quantity and quality of merchantable products obtained. The chief products obtained from the distillation of a petroleum are divided into products having a specific gravity within a certain range, and the percentage of such products varies widely with the kind of petroleum used. The first product of distillation, having a specific gravity of from 0.60 to 0.69 is called rhigoline, petroleum ether, or gasoline. It is by far the most important product, and efforts are constantly being made to increase the yield. The second product to come off is aviation grade spirit, with a specific gravity of 0.69 to 0.73. Next comes ligroin or light kerosene having a specific gravity of 0.73 to 0.79. The fourth and next important petroleum product is lamp oil, kerosene, or paraffin oil, having a specific gravity of 0.79 to 0.82. The next product, gas oil or solar oil, is comparatively unimportant, and is used as a fuel or as a light lubricating oil. Its specific gravity ranges from

0.82 to 0.88. The third most important petroleum product, having specific gravity of 0.83 to 0.95, includes the lubricating oils, Diesel engine fuels, or boiler fuels. This fraction includes, as may be seen from the specific gravity, the gas or solar oils. The last division, having a specific gravity or 0.87 to 0.94 also includes the petroleum jellies and paraffin waxes. From a general survey of petroleum products, an estimation of the percentage composition of a crude oil may be as follows:

	per cent
Benzene or gasoline	15 to 55
Naphtha	0 to 10
Kerosene	10 to 35
Bottoms or heavy oils	25 to 75

These figures, of course, vary for petroleums coming from different sources.

Fuel tests

There are many problems of fuel research which must be solved before the proper fuel may be chosen. These problems are not confined alone to the chemical constitution of the fuel being used, but hinge upon many principles of mechanics and thermodynamics, which must be considered in other laboratories outside the chemistry laboratory. Chief among these problems, are two outstanding difficulties which must be met and overcome in the construction of the engine and the choice of fuel. These are the problems of multi-cylinder distribution of the fuel and the formation of the proper mixture of fuel and air after it enters the cylinder. The problem of distribution is, of course, reduced to a minimum where only one- and two-cylinder engines are employed, but when we consider the present day six-, eight-, or twelve-cylinder engine, we encounter a great deal of difficulty. Radical changes in carburetion, with the invention of the so-called "Hotspot" manifold, "Double-jet" carburetor, etc., have come into effect, and engineers are continually trying to improve the quality of carburetion. Upon this depends the chemical constitution of the explosive mixture going into the cylinder. It is necessary that we get mixtures of fuel and air all of the same strength into

each cylinder, or we will be troubled by knocking, carbonization, irregular firing, and a general loss of efficiency within the motor. By experiment it was found that it makes very little, if any, difference whether a gas is dry, nebulized, or vaporized, just as long as the proper mixture goes into each cylinder. Hence, we encounter the problem of proper distribution. In the earlier days of the internal combustion engine, fuels were of high volatility, and as long as there were no mechanical defects within the engine itself, there was very little trouble with carburetion. At the present time, however, with the gasoline manufacturers cracking more and more of the petroleum in an attempt to produce a
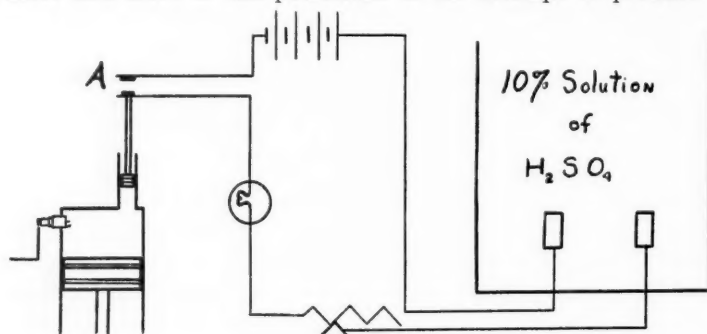
Fig. 2

greater yield of fuel per volume of petroleum, the fuel is necessarily of lower volatility. Hence, it becomes the problem of the engineer to make the engine to suit the fuel available, with the result that the many problems of distribution are encountered.

As an example of the way in which the tests on fuels were carried out, the problem of knocking or detonation of a kerosene fuel was attacked in the laboratory, under the direction of Charles F. Kettering, an engineer associated with the General Motors Corporation. It was found that kerosene knocked because it condensed under pressure and would not absorb enough heat to volatilize. Hence, the problem was, how to make it volatilize. Now, in the field of botany, it is a well known fact that leaves which are red on the under-side absorb more heat than those

which are not. Consequently, Kettering arrived at the theory that if a red color could be imparted to the fuel, it would absorb enough heat to volatilíze and cease knocking. In order to test the theory, iodine was added to the fuel, which imparted a red color. Curiously enough, the knocking did stop, but it was later found that these results were obtained because of the chemical properties of the iodine and not due to the red color. The details of the method used in testing the detonating characteristics of fuels are given in figure 2. When the explosion occurs in the cylinder, it drives the small pin upward, so that a contact is made at (a). This closes the circuit, and the electrolysis of the sulphuric acid solution is started. For a certain volume of fuel, there is a certain volume of hydrogen and oxygen liberated in the solution. In this way the comparison of detonation characteristics for many different fuels may be made with positive and accurate results.

A great many tests have been made in comparing the efficiencies of gasoline and alcohol as fuel for the internal combustion engine. In 1912 R. M. Strong and Lauson Stone carried out investigations using five engines, two of which were Otto gas engines, one Nash gas engine, and one Nash and one Otto alcohol engine. All were standard engines of the single cylinder, four-cycle type, having a speed of two hundred and sixty revolutions per minute. As a result of these investigations, it was found that the thermal efficiency is the same for both the alcohol and gasoline engine, while the load on the engine constitutes the most important variable in its operation. What is more important, it was found that explosive mixtures of alcohol and air could be compressed to higher temperatures, without pre-igniting, than could mixtures of gasoline and air. This made it possible, from the economical standpoint, to construct the alcohol engine so that it is equal to the gasoline engine. Another discovery, relatively unimportant, was that approximately twice as much air is required for the explosive combustion of gasoline as for alcohol.

Many blended fuels have been tried, but so far have not reached a very wide commercial practice. Blends of coal-tar distillates, benzol, toluol, and alcohol, with gasoline are the most common

blended fuels on the market today, yet their worth is really not yet proven. They have been tried with the idea of preventing pre-ignition, or as anti-knock fuels in which case greater compression and more efficiency result. Another recent development is the addition of lead tetra-ethyl to gasoline as a high compression fuel, which seems to have done a little in the way of preventing pre-ignition.

Gasoline

Gasoline is defined, by the Committee on Petroleum Products and Lubricants of the American Society for Testing Materials, as "A refined petroleum naphtha which by its composition is suitable for use as a carburant in internal combustion engines." This closely approximates the definition of petroleum naphtha, a generic term applied to refined or unrefined petroleum products and liquid products of natural gas not less than 10 per cent of which distills below 240°C. when subjected to distillation in accordance with the current method of testing of the American Society for Testing Materials of petroleum products of this nature.

By far the greatest demand on petroleum products comes from the motor industries for gasoline and lubricating oils, and the value of the gasoline alone is more than that of all the other petroleum products combined. Gasoline is almost wholly used in marine engines, stationary engines, airplane engines, automobiles, motor-cycles, motor-boats, tractors, and tanks. However, in spite of its varied uses, the same grade of fuel is sufficient for all these different uses, except, perhaps in the airplane, where the feature of extreme purity and light weight coupled with a minimum of fire hazard must be considered. Up to the present time no suitable substitute for gasoline has been evolved, hence the importance of gasoline and gasoline production is being increased daily. In 1904, the yield of gasoline from a crude petroleum was only 10.3 per cent, while in 1918, the figure was increased to 26.1 per cent, an increase of 155 per cent. At the present time, refiners are attempting to obtain still greater yields. This means that the product being obtained, due to better and more accurate means of distillation and cracking, has a lower volatility, or higher boiling

point, than formerly. This has necessitated many changes in engine design and carburetion, thus settling the old question of whether to produce the fuel to fit the motor or the motor to fit the fuel. Yet the increased yield of gasoline per quantity of crude oil is limited by the number of other petroleum products which which must be produced. We must have lubricating oils and fuel oils. This, eventually, will resolve itself into a question of the relative prices of fuel oil and gasoline. When the price of gasoline reaches the point where it is more profitable to crack the oil rather than use it as a fuel, the production of fuel oil will either decrease or its price will increase to a point where it is not profitable to crack it.

Horning in "American Petroleum, Supply and Demand," has stated that the miles per gallon for the country can be doubled within 15 years after the price demands the change. It may be seen from this that a modification of engine design and increased production of gasoline per barrel of crude oil will eliminate a great deal of waste prevalent today. But these two must go together. After exhaustive research, the General Motors Corporation states that it is possible to make automobiles go twice as far on a gallon of gas as they do today. The present internal combustion engine transforms only five per cent of the energy in the gasoline into useful work. Hence it is possible to increase this to ten per cent, and further developments along this line will come in the near future. However, such developments cannot and will not come suddenly, but will extend over a long period of time.

The United States is by far the greatest consumer of gasoline, most of which is used for automobiles. Of the total number of motor cars in the world, 83 per cent are operated in the United States above. At a meeting of the American Society for Testing Materials, a Commitee of Eleven compiled the following table of gasoline consumption. The figures are based on the average yearly consumption as compared to the increasing number of automobiles being built each year.

year	consumption
1920	101,207
1921	107,488
1922	127,907
1923	159,172
1924	185,281
1925	218,215
1930	315,444
1935	365,780
1940	403,045
1945	431,560
1950	455,549
1955	475,880

Consumption in thousands of barrels (42 U. S. gal. per barrel).

E. W. Deane in Bureau of Mines Technical Paper No. 214 gives the following requisites for a gasoline:

1. The gasoline should not contain too large a percentage of highly volatile products, which tend to cause a large evaporation loss and excessive danger in handling and storage; but should contain enough volatile constituents to permit starting an engine under unfavorable conditions without pre-heating.

2. The gasoline should not contain any considerable percentages of heavy or non-volatile constituents, which after delivery into the engine cylinders cannot be atomized and burned.

3. The gasoline should not contain material that, after combustion, leaves a residue that collects in the motor.

4. The gasoline should be free from substances that attack metal either before or after combustion. Unremoved acid falls under this heading.

5. Neither the gasoline nor its products of combustion should have a strong or markedly disagreeable odor, since this is objectionable to users of automobiles.

6. The gasoline should be free from non-combustible materials such as water and dirt.

Since the present day trade requires a water-white and sweet smelling product it is necessary to remove the unsaturated hydrocarbons which cause a gasoline to go "off color" when in storage. These hydrocarbons are considered the most valuable constituents of gasoline, especially those of the unsaturated olefin group, hence

an appreciable part of the available motor fuel is destroyed
by treatment with sulphuric acid to satisfy this demand for a
water-white product.   The di-olefins however cause tarry deposits
upon combustion, hence they are objectionable.   Thus, while
odors are objectionable to the consumer, they are not necessarily
an indication of a poor gasoline.

A survey of the results of the various tests made upon gasoline
reveals the following information.   Specific gravity serves to
indicate the presence of any considerable percentage of materials
other than those normally present in gasoline, such as benzol,
alcohol, etc.   The distillation range of a gasoline reveals informa-
tion regarding starting qualities, ease of vaporization and distribu-
tion, tendency toward contamination of the lubricating oil, com-
position, knocking characteristics (if the source and composition
of the fuel be known), and tendency to deposit carbon in the
motor.   Acid present indicates that (a) the sulphuric acid used in
refining was not completely removed or (b) that sulfonic acids were
formed in the gasoline in the effort to produce a white product,
and were not subsequently removed.   The presence of either of
these acid materials is harmful and unnecessary.   Percentage of
unsaturation is the measure of the tendency to form gums.   The
content of gummy materials present is harmful and unnecessary.
The percentage content of aromatic hydrocarbons such as benzol
serves to indicate, in a fair degree, how far the gasoline may be
compressed without knocking.   The purity of a fuel as to its
content of paraffin hydrocarbons is representative of the general
run of gasolines sold east of the Rocky Mountains.   The alcohol
content of the fuel has the same effect as benzol, in that it in-
creases the compression operation without knocking.   The pres-
ence of alcohol also indicates the presence of a third material,
which must be used to bind the alcohol with the gasoline.   These
two substances are not miscible in each other.   For a more
detailed explanation of the above-mentioned tests, I refer the
reader to Bulletin No. 4, of the General Motors Fuel Service,
June 15, 1921, on the testing of gasoline.

A brief mention may be made here of the production of gasoline
by its condensation from natural gas.   This gas is usually found

in contact with oil-bearing rock, although in some cases gasoline has been condensed from gases which apparently have no contact with crude petroleum.   The first gasoline made in this way was made in Titusville, Pennsylvania, in 1904, while at Tidioute, Pennsylvania, a company still produces gasoline for the market in this way.   The gases from which gasoline is produced are called the "wet gases," whereas a "dry gas," in which methane is the only combustible constituent, is of no value for gasoline extraction.

Fuel oils

The fuel oils are those distillation or "cracked" products of petroleum having a specific gravity ranging from 0.85 to 0.95. The color ranges from an almost water-white to a deep, heavy, black, asphaltic base crude oil.   These oils are used a great deal for heating plants, and their only application as far as the internal combustion engine is concerned, is to be found in the heavy-oil and Diesel engines.   The same specifications of fuel apply to both types of engine.   Other fuels may also be used in these engines.   These are the lignite-tar oils and some vegetable oils. However, the main source of fuel is petroleum because the petroleum oils gasify around 400° to 500°C., and this is about the working temperature of the Diesel engine.   The petroleum oils possess this property because of the unstable condition of the carbon atom.   Those petroleums rich in saturated hydrocarbons naturally burn the most readily.   From this we see that a decreasing hydrogen content means increasing resistance to ignition, hence the asphaltic-base oils do not burn as readily as the paraffin-base oils.

The properties of a petroleum fuel-oil requisite for the Diesel engine are listed as follows:

a. The fuel should burn completely without leaving any soot, coke, or ash.

b. It should be sufficiently fluid at ordinary temperatures to flow to the fuel pumps and valves without clogging the pipes.

c. It should be free from highly volatile oils which would ignite too easily and increase the fire hazard.   Because of the high temperature

encountered in the combustion chamber such oils do not give best results and are apt to cause knocking.

d. The fuel should have a high heating value, in order to make the engine most efficient, since it operates at a high temperature.

e. The fuel should be free from any mechanical impurities that would tend to clog pipes and vents.

f. It should be free from water, as this lowers the heating value of the fuel and may even prevent ignition of the fuel.

Kerosene

As far as use in the internal combustion engine is concerned, kerosene plays a very unimportant part. The disadvantage of the necessity for pre-heating the engine cylinder and of carbon deposition far offsets the advantage of economy of price per unit volume.

Practically the only use of kerosene as a fuel for the internal combustion engine is to be found in the farm tractor and in some stationary engines. It is necessary to first heat the cylinder either from the outside or by running the engine with some other more volatile fuel, such as gasoline or alcohol. After the necessary temperature has been reached, then the kerosene may be used. Owing to the large amount of unsaturated compounds present in kerosene, there is an extremely large amount of carbonaceous material deposited upon ignition, hence in order to remove this it is necessary to inject some water along with the fuel. The presence of the moisture softens the deposit and makes it possible to remove it easily by the force of the explosion within the cylinder.

LUBRICANTS

A lubricant is that smooth fluid or semi-fluid substance, such as oil or grease, introduced between two moving surfaces to prevent solid friction, that is, to prevent their coming into direct metallic contact. All bearing surfaces, however smooth to the naked eye, are microscopically rough, and unless some medium is introduced which will cover these asperities and fill up the depressions, the surfaces will inter-lock and give rise to friction, heat, and rapid

wear. When the moving parts are separated by a lubricant, friction then takes place in the molecules of the liquid itself. Also a copious circulation of oil through bearings carries off the heat of friction, and makes possible the conditions requisite for efficient lubrication.

With probably only one exception, castor oil, all lubricating oils used in the internal combustion engine are derived from petroleum. They range from 0.83 to 0.95 specific gravity, and the color usually from a pale yellow to black, depending on the treatment during the cracking process. The internal combustion engine is without a doubt the most difficult to lubricate of all known mechanisms, due to the unavoidable necessity of exposing large lubricated cylinder areas and other surfaces to high temperatures.

The suitability of an oil for the proper and efficient lubrication of all internal combustion engines is determined chiefly by the following factors:

A. Type of cooling system. (Operating temperature).
B. Type of lubricating system.
C. Rubbing speeds of contact surfaces.

If the operating temperatures, bearing surface speeds, and lubricating systems were identical in all engines then a single oil could be used in all engines with equal satisfaction. The only change then necessary in viscosity would be that due to climatic conditions. As engines are now designed, three grades of oil are necessary for the lubrication of all types, with the possible exception of the Knight sleeve-valve engine, air-cooled engine, and some engines which operate continuously at full load. These three grades may be designated as light, medium, and heavy oils. The feature of the load carried by the engine is of prime importance in the specification of engine lubricants. In the list of "full-load" engines are:

A. Marine engines.
B. Racing automobiles.
C. Airplane motors.
D. Farm tractors.
E. Stationary engines.

The "variable-load" engines are:

      A. Pleasure automobiles.
      B. Commercial vehicles.
      C. Motor-cycles.
      D. Stationary engines.

A list of the requisites for a lubricating oil is as follows:

A. It must have the necessary body to withstand the severest pressure in service for which the oil is intended.

B. It must keep a continuous film of oil between the rubbing surfaces.

C. It must fill up the inequalities of the surface.

D. It must spread over the surface rapidly, with the requisite degree of adhesiveness to remain between the rubbing surfaces without creating undue friction and heating.

E. Requisite mobility or fluidity at all seasons of the year, and all climates, without impairment to the necessary intrinsic lubricating body for the required surface.

F. Freedom from tarry and asphaltic bodies.

G. It must be non-drying and non-gumming.

Lockhart in his book, the "Lubrication of the Internal Combustion Engine," has compiled a list of the specifications for oils used in various types of engines. In the stationary gasoline engine, a straight distillate having a viscosity of 220 to 450 Saybolt and flash test of 400°F. is ordinarily used. In the motor boat, where the oil is fed with the gasoline, an oil of 200 to 270 Saybolt at 100°F. is used. Oils of 350 to 800 Saybolt at 100°F. are used in the motor-cycle. The kerosene engine requires an oil of 450 to 650 Saybolt at 100°F. with a flash test at 400°F. The consumption is extremely heavy due to the necessity of pre-heating the cylinder to aid combustion. The airplane engine, because of its extreme lightness, high speed, air-cooling, and continuous operation at full capacity, requires the best oils obtainable. It must have a high specific gravity, around 30° Beaume, and a flash test well above 400°F. The cold test must be about 15°F. Usually straight distillates or heavy mineral distillates blended with light high grade cylinder stock are used.

Tests of lubricants

The tests selected as denoting the quality of lubricating oils are those of viscosity, volatility, cold test, susceptibility to oxidation, and emulsifying properties.

Viscosity is defined as the number of seconds required for a definite volume of oil, under an arbitrary head, to flow through a standardized aperture at a constant temperature. There are several different methods of measuring the viscosity of an oil, but all work on the same principle. The difference lies only in the method of treatment, not in any fundamental principle. The instrument used in measuring viscosity is called the viscosimeter. There are five different types of viscosimeters:

A. The Saybolt viscosimeter, which will be later explained.
B. The Tagliabue viscosimeter sometimes used by oil refiners and consumers.
C. The Engler viscosimeter, used chiefly in continental countries.
D. The Redwood, used in the British Isles and Colonies.
E. The Pennsylvania R.R. pipette.

The Saybolt viscosimeter consists of a large bath or container, filled with the oil to be tested, and heated to a certain temperature. After a constant temperature is reached, the oil is allowed to run out of a stop cock, of standard size, into a graduated ontainer. The container used with the Saybolt viscosimeter is a 60 cc. flask. At the time the stop cock is opened, a stop watch is started, and the time necessary to just fill the flask is recorded. This is called the viscosity of the oil at the given temperature and is known as the Saybolt Universal. Thus, an oil whose Saybolt is 200 at 50° is one which flows 60 cc. in 200 seconds at a temperature of 50°C. The visosity of an oil is a large factor in the horsepower developed by an engine. For instance, if a very heavy oil is used, there is a strong fluid resistance to the motion of the sliding surfaces, and more work or energy is required to overcome this. This results in an increase in fuel consumption. Figure 3 has been derived by the Tide Water Oil Company of New York, and is designed to show the effect of viscosity on horsepower and fuel consumption.

The Chill or Cold Test of an oil is the lowest temperature at which the oil will pour. This is of importance where an oil must flow through pipes and circulating systems, although it has nothing whatever to do with the lubricating or heat resisting qualities of an engine oil.

Effect of viscosity on horse-power, fuel and oil consumption.

Viscosity at 100° Fahrenheit
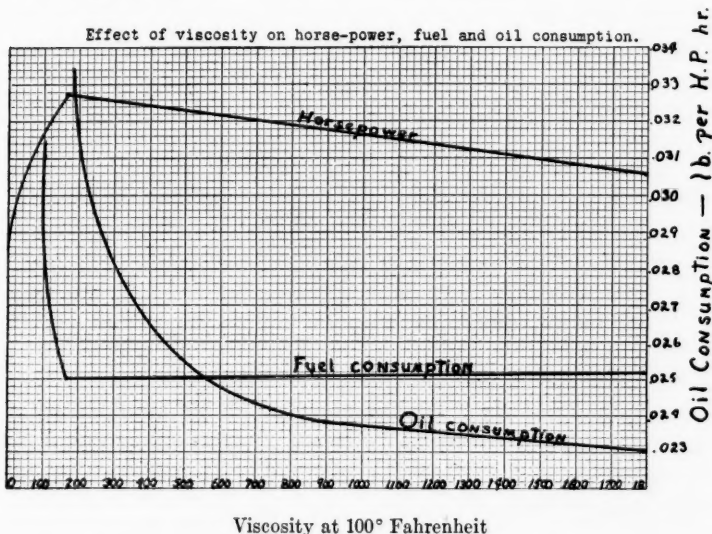
FIG. 3. In determining the above curves, oils made from paraffin and intermediate base crudes were used. The light, medium, and heavy oils all possessed approximately the same degree of volatility. This statement is necessary because of the fact that the property of viscosity alone is not the sole determinant of oil consumption. As shown by the curves above, oils possessing the same volatility will give a consumption in an engine correspondng to their viscosity, high or low, whereas oils having the same viscosity but widely differing degrees of volatility may also show a decided difference in consumption.

Volatility is the vapor loss of the oil and is measured by the quantity of low-boiling constituents of the oil. If an oil is to be used in full-load engines there must be a certain quantity of low-boiling constituents, or there will be too great a tendency for carbonization within the cylinder. On the other hand there must be a limit to these low-boiling constituents or the factor of the consumption of the oil becomes quite large. Hence, in the

ordinary lubricating oil, a balance has been struck, supposedly, between rapid carbonization and fuel consumption.

Heat is the greatest enemy of hydro-carbon lubricating oils because it results in their decomposition and formation of non-lubricating products. Hence it is necessary to determine the relative heat resisting properties before specifying oil for the internal combustion engine. Examination of crank-case sediment has shown that the decomposition of oil results in solid hydro-carbons mixed with metal dust or metallic oxides. In testing the oil for oxidation, it is heated to the actual heat found under operating conditions.

The tendency to emulsification within the oil shows the presence of sulpho-compounds, formed by treating the oil with sulfuric acid for the removal of undesirable hydro-carbon compounds. The acid is supposedly all washed out or otherwise entirely removed, yet poorly refined oils sometimes contain acid. The proof of the presence of acid is shown by shaking a sample of oil with water and noting whether the oil and water are completely separated or are mixed with one another. If the oil floats as a curdled mass in the water, the presence of acid is shown. An acid-containing oil is apt to eat or corrode valves and valve seats, causing pitting of the valve surfaces and consequent leakage.

Brief mention may be made here of lubricating greases, although they have no application as far as the internal combustion engine is concerned. The greases are really sodium, aluminum, or calcium soaps (salts of the high molecular weight organic acids) mixed with some light lubricating oil. As far as petroleum products are concerned, greases occupy a position of relative unimportance.

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NOTE: In accordance with a ruling of the postal authorities it has become necessary to change the name of this publication from "BULLETIN" to "JOURNAL" of the **SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY.**